FUNDAMENTALS OF ENERGY CONSERVATION IN BUILDINGS

A report prepared for the Environmental Quality Council of Montana

and

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by

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INTRODUCTION

This report considers the most fundamental ways in which energy may be conserved in buildings, and in no way does the author consider it a complete digest of ways energy might be conserved in buildings.

The report is written with the assumption that laymen as well as professionals will find it easily understood and useful in attempting to reduce energy consumption.

The context in which the information is considered involves the residential and commercial sector of our society. This sector consumes 33% of the total energy produced in the United States.[1] Specific information is presented as it may be applied in the state of Montana. Fuels considered are our basic fuels (coal, oil, natural gas, hydro, and atomic). It is assumed that the ideas or information presented as a means to reduce consumption will not affect our current standard of living and will have a minimum effect on our way of life.

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[1] Technical Options for Energy Conservation in Buildings - Building Environment Division Centre for Building Technology - Institute for Applied Technology National Bureau of Standards, Washington, D.C. - 1973.

Legislation is suggested as a means by which state government might be able to implement some of the information found in the report.

New forms of energy are very basically introduced, but are not considered in the bulk of the report because of the lack of conclusive data at the current state of the art.

CONVENTIONAL FORMS OF ENERGY

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Coal

Coal is our most abundant fossil fuel, but its use and development have the most serious physical environmental problems. It is a "dirty" fuel in that it fills the air with gaseous as well as solid particles. Most mining of coal requires stripping which has serious physical implications in the immediate area which is affected directly by such practices. The future use of coal is expected to increase as most Montanans are aware.

Petroleum

Reserves of petroleum are much less abundant than coal. This factor, plus the fact that our motorized society (110 million motor vehicles) depends on this product to keep moving, places this fuel in an extreme crisis stage in the overall energy picture. World reserves are expected to expire about the middle of the next century if current forecasts of supply and demand are valid. The shortage of the supply of this fuel has affected the greatest number of people and has therefore attracted the most publicity. Oil is used to generate only about 10% of our electricity and of space heating and is therefore not considered to be a major source of energy for buildings.

Natural Gas

Natural gas is the cleanest, most efficient, most easily transported fuel we use today. It provides 1/3 of the nation's total energy and 25% of it is electricity. Resources of natural gas are limited and discoveries are usually associated with oil discovery, so future large finds seem improbable.

In this report it has been suggested that electric utilities be encouraged not to use natural gas for steam electric generation because it is a very inefficient use (40% efficiency) of this limited fuel. In buildings, efficiencies of between 70 and 80% are possible using total energy systems and at least 70% using a gas fired furnace only.

Water Power - (hydroelectric)

Hydroelectric power production is our most natural form of power production. It produces about 4% of our power at this time. Most of the best sights have been utilized, so there is expected to be very little growth in the use of this source of power. Rising land costs and environmental demands are beginning to make hydro power less economically attractive to utilities.

Nuclear Energy

Nuclear Energy is utilized for electrical production in many areas of the country. Problems associated with such a form of power are the hazards of radioactive wastes, large amounts of waste hot water, and the inefficient use of a scarce fuel, uranium. We may run out of uranium by the year 2000 if we continue to use conventional nuclear facilities.

new [illegible]

Fundamentals of Energy Conservation in the home and in larger buildings will be discussed in the context of these conventional forms of energy. The great demand by society for these forms of energy and the failure of production and discovery to keep up with the projected demand are what is creating our current "energy crisis". The fundamentals for conservation are meant to encourage a reduction in the rate of consumption of these energy forms in our homes and public and private buildings. The steps mentioned should affect the residential/commercial sector of our society which consumes about 33% of the

U.S. energy production today. The energy demand from this sector of society is expected to decrease in the future, and if some of the suggestions of a report such as this were adhered to by a majority of people involved in this part of our society, the decrease in energy demand would be accelerated.

ENERGY CONSERVATION IN THE HOME

ENERGY CONSERVATION IN THE HOME

Introduction

Energy conservation or reduction of energy consumption will be discussed as it relates to our most familiar environment, the home. Although residential energy use is by no means the major use of resources in our society, it is believed that by understanding the measures which one must adapt to conserve energy in the home, one will more easily accept and understand the much greater measures required to conserve energy in their business or place of employment.

The home will be described beginning with the raw site, proceeding to construction and finally operation and maintenance of the structure.

Various energy conserving measures will be discussed and suggestions for possible legislation will be introduced where they seem appropriate.

This discussion of the house is a consolidation of material from many sources into a coherent whole. The nature of the steps proposed for conservation are not particularly sophisticated and usually fall into the category of common sense. Unfortunately, the simplicity of the measures proposed are of a nature which may be hard to accept by the average individual in our unnecessarily complicated society.

Siting

Placing the building on the site involves consideration of all the natural elements both above and below ground which will affect the completed structure both in a positive and negative attitude.

Soil should be tested to determine ability to accept a structure. The need for special foundations to compliment poor soil structure requires more materials and labor.

Soil should be tested to determine drainage characteristics. The poorer the drainage characteristics, the more area is required for the dispersal of on site sewage and thus greater material usage. If special equipment is required to prevent water table fouling, we again have an increased consumption of energy.

Serious consideration should be given as to whether or not we should allow large areas of highly productive agricultural land to be used for building sites. Prime agricultural soils contain many natural nutrients and therefore usually require less fertilization and conditioning to produce a successful crop. If we allow these soils to be developed as building sites, the farmer will be forced to till less productive land in order to produce our agricultural needs. There will be a greater consumption of energy in terms of increased utilization of fertilizers and increased mechanical irrigation in many instances. Nationally this may not be a crucial problem, but in the state of Montana it becomes a major consideration because of the loss of farmland due to saline seep and coal mining as well as home construction.

Natural features of the land's surface should be considered. Rock outcroppings may give wind protection or provide shade. Trees may provide the same forms of protection. Slopes create winds as the temperature of the air changes through an average day. Coulees may be very pleasant or unpleasant depending on their orientation to prevailing breezes.

Climatological data should be compiled on a local basis and the house should be evaluated as to the micro-climate which it creates. This climatological data includes annual rainfall and snowfall, annual temperature, diurnal temperatures, or typical extremes, wind rose diagrams and reference to undesirable characteristics of wind and sun path diagrams.

In considering site selection, this data may be combined with the knowledge of natural elements of the site to assess the good and bad characteristics of the site. We must keep in mind the fact that we are trying to make best use of natural assets in terms of protection from natural liabilities. Concerning energy conservation, such an analysis of the site helps in protecting the home from the harshest winter and summer conditions. It is in retaliation to these conditions that we expend our greatest amounts of energy for heating and cooling of the living space.

In winter we cannot do much about the cold air, but can protect our homes from harsh winds which tend to chill factor amplify the cold. Likewise, in summer one cannot prevent hot days, but one can site the home in such a manner that it will be within air movement areas or shade to reduce the amount of radiant heat which directly penetrates the home.

If there are no natural elements to provide sun and wind protection, then the home builder should be encouraged to provide such features in the form of plantings or actually constructing windbreaks and sun screens. A legislative program, which would induce the planting of trees for shade and wind protection, might be instituted in the form of a tax incentive. Reasons for iniating such a program would be for the practical energy conserving aspects, the induction of oxygen into the air, as well as the aesthetic value of the trees to the individual and the community. This legislation could come at the city, county or state level.

In areas where trees are not easily grown or are not felt necessary, groups of buildings, or parts of homes such as house and garage, may be situated in such a way that they create windbreaks or shading.

Proximity of utilities and, in some cases, public transportation should become a criterion of home siting. These steps conserve energy by reducing transmission loss of electricity and reducing the use of fuels to power personal forms of transportation.

The Design and Construction of the House

In the first stage of the life of the structure, the materials, details and design in correlation with the information which was mentioned in the previous section concerning siting we considered.

Foundation

The foundation is the element of the structure which distributes the loads directly to the surface of the earth. The choice of a foundation is determined by many soil and topographical problems which are not within the scope of this study. Relative to energy conservation it may be stated that a layer of insulation of some form should be provided between the raw elements and any conditioned space. This insulation hinders the direct transmittance of heat or cold to the conditioned space. A vapor barrier should also be provided to impede the movement of moisture through foundation materials.

Foundation materials are strong in compression and have excellent weather resistant properties. Concrete is perhaps the most common material. Treated wood is an excellent material for pile foundations. Both of these materials require a relatively small amount of energy to produce.

Floors

Conserving energy in floors becomes a matter of insulating any floor which will be exposed to temperatures which will be either higher or lower than the temperature of the conditioned space. In the case of concrete slab floors, a rigid insulation as well as a vapor barrier is necessary for Montana's climatic conditions.

Joist floors with a heated basement or heated crawl space require only a sheet of foil and air space to achieve positive results. Unheated crawl spaces should be insulated to the specifications of a wall under similar conditions.

What is the life of the home??

Flooring materials should be selected to withstand the use conditions over the life of the home. ? This measure conserves energy by possibly eliminating replacement of materials over the life of the home. In choosing flooring materials, energy can be conserved through greater lighting efficiency if reflectance of the floor surface material is between 21 and 39%.[1]

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[1] B. Givoni, Man, Climate and Architecture (Elsevier Publishing Co., Ltd., London, 1967).

Walls

The walls of a structure constantly receive the abuses of weather such as wind, rain, snow, heat, cold and sun exposures. In most cases of residential construction, the walls also carry the load of the roof. They are one of the most prominent visual features of a home. Therefore, they must be designed to perform their many utilitarian tasks as well as be attractive.

Insulation

Insulation material is the prime element for energy conservation through walls. This insulation material has the dual purpose of keeping cold air out in winter and warm air out in summer. In Montana's climate, 3 1/2" of glass fiber insulation with foil on the heated side is a very adequate amount. Two inches of sprayed polyurethane is excellent and this form of insulation has the added advantage of filling small cracks and acting as a vapor barrier along with a great ease of installation. Insulation should be applied carefully and completely to prevent leaks of air between the living space and outdoor areas.

Wall materials should be selected for their ability to resist the transmittance of heat. This implies that each element of the wall should be a good insulator. Layers of materials with air spaces are very effective in providing resistance to heat transmittance. The ability to resist heat transmittance or a reduction in the flow of transient heat through a material is of particular design importance. It should be noted that heat will eventually penetrate through the wall of the structure and the time lag factor gives an indication of the amount of time it will take heat to pass through a particular material of a particular thickness. The designer should attempt to create a structure which will have a balanced time lag. This means that the East side should be cool before the south side warms and the south cool before the west side warms. The north side is of negligible value. Without this balanced time lag, a very uncomfortable interior heat gain will be created.

Walls should be shaded whenever possible to help block direct sun rays which accelerate heat transmittance. The color of a wall is very important in this respect. Studies performed by B. Givoni of the Building Research Station Technion, Israel Institute of Technology indicate absorption coefficient of various colors.

The architect may use these figures in conjunction with material time lag to create balanced heat penetration of the structure. For Montana the most desirable combination of materials is to insulate all four walls and provide a time lag or heavy mass or different composition material wall on the western exposure as well as interior masses to balance daily temperature fluctuations.

Energy may also be conserved by careful detailing of joints where both air and moisture might penetrate the conditioned interior space.

Doors and Windows

To conserve energy in the placement of exterior doors, it is important that they be oriented in such a way that they do not receive direct contact with harsh winds. Direct sunlight is also a bad element for doors because of the direct transference factor and expansion-contraction problems. Doors should be weatherstripped to make them as airtight as possible to reduce heat loss or gain through infiltration. Material should be considered with respect to U factors and time lag characteristics.

Windows are a major contributor to heat loss and heat gain in all structures. In the home, movable windows should be placed so that patterns of cross ventilation will be created within the conditioned space.

All windows, both fixed and movable, should have weatherstripping, and storm windows or doubleglazing to limit infiltration as well as heat transference.

It is a bad practice to allow windows which have sun exposure to go unprotected in warm periods of the year. Montana's climate is such that it is an advantage to have direct sun in winter, but a disadvantage to have direct sun in summer months. Therefore, sun shading devices should be of a nature to allow for this phenomenon.

The fact that no direct sun rays penetrate the interior space makes exterior devices more effective than the interior ones in Montana.

Roof

The roof of a structure serves the purpose of waterproofing the enclosed space from rain and snow. It gets a great deal of direct sun and is therefore a major contributor to heat gain in summer months. Roof areas should be ventilated because of this heat buildup. The ventilation causes a heat loss in winter months. The architect must try to minimize the effects of these losses and gains in designing an energy conserving home.

During summer months the air space in an attic or below a flat roof may be as high as 40° above the outside temperature. To prevent this heat gain from reaching the living space, the designer may take the following steps. Ventilation should be provided equal to 1/300th of the attic floor area. Inlet holes should be provided in the low soffitt areas and outlet holes should be in the upper eave area. This will produce natural ventilation currents. Insulation (6" in Montana) should be provided between the living space and the attic area. An attic fan is justifiable in many cases to rid the space of heated air. Light colored or reflective roofing materials are another major consideration for reducing heat gain.

Reduction of heat loss in winter may be accomplished by sealing any infiltration cracks between the living space and the cool attic spaces with particular attention paid to the detailing of attic access areas.

Building Shape

The optimum form for a dwelling is determined by applying seasonal variations to the basic cubical shape. According to the studies of Olgyay,[2] this shape for Montana would be a ratio of 1:1.1 (length to width) with the elongated side along the east-west axis. This shape is an average with optimum winter shape being 1:1 and summer being 1:1.3. The elongation is a result of the fact that heat gain can be achieved on the south side in winter months. Heat gain in summer is greatest on the east and west sides, therefore, the smaller dimension on these sides.

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[2] Victor Olgyay, Design With Climate (Princeton University Press, Princeton, NJ, 1963).

Comparison of Orthodox House vs. Environmentally Aware House

Orthodox House - a structure which has neutral features in regard to the climactic environment.

Square Plan

Floor area 1225 sq. ft.

Each side has 280 sq. ft. surface

220 sq. ft. dark colored wood frame construction

Two 5' x 6' windows totaling 60 sq. ft. glass area

21 sq. ft. door is on the north side.

Flat pitched roof covers total area.

In the cool area of the county (Minneapolis, Minnesota), the performance of this house in terms of heat loss and heat gains are as follows:

Heat Loss (winter) Heat Gain (summer)

Woodframe construction Woodframe wall

Heat Loss (winter) Woodframe construction	Heat Gain (summer) Woodframe wall
E - 5%	E - 1%
S - 5%	S - 1%
W - 5%	W - 1%
N - 5%	N - 0

Window areas	Window areas
E - 10%	E - 25%
S - 2%	S - 15%
W - 10%	W - 25%
N - 12%	N - 7%
Roof - 13%	Roof - 14%
Infiltration - 33%	Heat created indoors-12%
4% gain through heat created inside	Loss of 1% infiltration

In his study, Olgyay changed the orientation, used overhangs and shading, ventilated roof construction, double glazed south window, weatherstripping and ventilated appliances.

Heat Loss (winter)	Gain (summer)
E - 8%	walls
S - 5%	Negligible
W - 8%	
N - 10%	
Window areas	Window areas
E - 7%	E - 5%
S -	S - 24%

W - 7%	W - 5%
N - 9%	N - 5%
Roof - 21%	Roof - 31%
Infiltration - 25%	Infiltration - 3%

11% heat gain from 150 sq. ft. double glazed south window
heat created inside 4%

Improvements on seasonal basis, winter - orientation and rearrangement of openings (+82.931 BTU gain) - 12%; reduction in infiltration (+119.788 BTU) - 17%; cut in connection through glass area by use of double glazing (100.95 BTU) - 15%. Applied ventilation of appliances works negatively at 2%.

The total reduction of heat loss by a balanced house is 42%.

In summer, conditions are improved as follows. Orientation shape rearrangement of openings (-19.650 BTU) - 8%; shading of glass surfaces (-141.330 BTU) - 54%; roof alteration by light color and ventilation (-14.169 BTU) - 5%; shading of wall surfaces (-9.573 BTU) - 3%; ventilation of appliances (-10.900 BTU) - 4%; the total reduction of heat gain is 75% as compared to the orthodox house.

The yearly importance of each factor as they have been described takes the following order.

1.	Reduction in infiltration	28%	Heat loss related
2.	Cut of heat loss by glass (double glazing)	24%	" "
3.	Orientation	22%	Heat gain related
4.	Shading of glass	22%	" "
5.	Alteration of roof	2%	" "
6.	Wall shade	2%	" "
7.	Vent of appliances	- 1%	" "

Conclusions

The conclusions which might be drawn from this study of the physical character of the home in its environment are almost as obvious as the measures which are suggested in the discussion. We can conserve the greatest percentage of energy through the use of insulation weatherstripping, and double glazing of windows. This finding is substantiated by the conclusions of short term energy conserving measures for residential and commercial construction as defined by the Executive Office of the President, Office of Emergency Preparedness in a study completed in October, 1972. These measures are for the reduction of heat loss during cold winter months. The next highest percentages are shading of glass and orientation in relation to climatic conditions. Here we are limiting heat gain during the summer months. The energy conservation comes from reduced full usage of the heating system.

In summer we are trying to protect the interior space and the total house from direct sunlight as much as possible. In Montana these measures should eliminate any need for air conditioning in most areas. If air conditioning is found to be a necessity, these measures can reduce the design load through a reduction in heat gain.

Legislation to implement some of the measures mentioned could be created through adoptions of building codes which would require adequate* insulation and weatherstripping. A tax incentive might be introduced for persons who employ energy conserving measures, and federal loans to persons who employ energy conserving improvements to existing structures. An environmental awareness statement might be required of home builders. This would be

*Adequate would have to be determined through technological study.

way of educating citizens with respect to natural conditions of an area, and how these conditions might be used to their advantage.

It should be noted that the implementation of the aforementioned information, or siting and physical elements of the house, conserves energy in an indirect way. All these devices help to increase the efficiency of the shell of the conditioned space. Direct energy conservation comes through the selection of mechanical systems and the operation and maintenance of these systems.

Mechanical Systems

Energy consumption in the home takes on the percentages shown in Fig. I . From this we can see that space heating is by far the greatest energy user with water heating a distant second in the home. Therefore, it is essential that very careful consideration be given to the measures mentioned for reducing heat loss as well as measures which will be discussed in terms of selection of fuel for heating systems.

Oil, gas, electricity, coal. Fuels which are readily available at this point in time are oil, gas,

Space Heating	53
Water Heating	12
Air Conditioning	8
Refrigeration	7
Lighting	5
Other Electrical	5
Cooking	4
Clothes Drying	1
Misc.	5
	100%

Fig. I. Energy Consumption in U.S. of the 33.6% Residential & Commercial by type of use.

Type of Furnace	Efficiency
Stoker-Fired Coal	60%-70%
Gas & Oil-Fired	
(a) Boiler	70%-80%
(b) Atomizing Burner with Forced Air	80%
Oil-Fired with Pot-Type Burner	70%

Fig. II. Toward Rational Power Policy

City	5° Setback	7 1/2° Setback	10° Setback
Minneapolis	8	10	12
Salt Lake City	7	9	11

Fig. III. Percent Fuel Savings with Night Thermostat Setback From 75°F.

electricity and coal. The primary criteria for selection of a furnace, water heater or thermal conversion system would seem to be the efficiency of the total system in converting fuel to useful heat. From Fig. II we see that gas and oil are the most efficient with coal running a close third. Electricity* is definitely last with an efficiency of 24-30%.

To clarify why electricity is so inefficient we must look at the total energy conversion process. The conversion of electricity to heat is almost 100% efficient in the home, but the conversion of fossil fuels, to produce steam to produce the electricity, is at best 40% efficient and with a 6-10% loss in transmission we can expect 34% at best for the total process.

Energy consumption is greatly increased by the use of electric heat. To produce 100 units of useful heat by a home furnace, one must burn fuel with an energy content of 125 to 167. To obtain the same result with electric heating, 278 to 295 units (in fuel terms) must be burned. Which means more air pollution and 2.5 to 8 times

*Refers to electricity produced by steam electric generator plants, or 80% of electricity produced in U.S. - steam plants include both fossil fuel and atomic plants.

as much waste heat discharged to the environment.[3] Commercially purchased steam heat is also much less wasteful than electricity and should be considered for use when it is readily available.

The obvious conclusion which must be drawn here is the fact that we must discourage the use of electricity for heating homes and domestic hot water if we are to conserve our dwindling supply of fossil fuels. A step which might be considered is to limit the use of natural gas and oil by utilities and reserve these fuels for domestic use. This might buy us time on reserves of these fast dwindling fuels. Low sulphur coal should be considered as a fuel for domestic use. The reserves are estimated to be in the vicinity of 400 years, and the efficiency of burning for home use is fair. The supply is very great in Montana, therefore, one would be dealing with a relatively efficient cheap fuel. This economic factor (cheap) should have particular appeal to most residential consumers.

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[3] Ashrae Guide and Data Book 1963 Fundamentals and Equipment, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

Regardless of what fuel is chosen, there are other steps which should be taken to insure peak efficiency and responsible energy use. A primary consideration should be given to implementation of a preventive maintenance schedule on the heating system. Filters should be kept clean and motors should be well oiled. Use of electric pilot lights is encouraged to reduce fuel wastage. It is suggested that room temperatures be lowered to 70 or 68° and more clothing might be worn to bring comfort to the individual. Approximately, for each degree above 70°F., it will cost about 3% more for heating in a typical U.S. climate.[4]

Setting your thermostat lower overnight can save energy. Fig. III shows the percent fuel savings for Salt Lake City and Minneapolis. This study was conducted by Honeywell Data of Minneapolis in 1973. The argument that by lowering the temperature does not save energy because you must reheat the walls, floors and furniture has been proven <u>false</u> by tests which concluded

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[4]<u>Technical Options for Energy Conservation in Buildings</u>, Building Environment Division Center for Building Technology (Institute for Applied Technology, National Bureau of Standards, Washington, D.C., 1973), pg. 27.

a wood frame house with the thermostat lowered from 75 to 65°F. at night for eight hours showed a 9% saving of heating energy for a 3°F. day and a 12% saving of energy on a 21°F. day.[5]

During heating seasons, it is an excellent idea to let the sun shine into the living space during the day, but the drapes should be drawn at night. The sunlight produces a greenhouse effect and decreases the load of the heating plant. Drawn drapes at night prevent radiation of cold air from the cold window surface and increase the feeling of comfort for people in the space.

Montana's warm dry days and cool nights in the summer months would seem to negate any necessity for summer cooling in the form of an air conditioner, but in areas where coolers are found to be necessary the following information should be taken into consideration.

Individual electric room air conditioners are probably the least efficient means of cooling.[6] For

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[5]Ibid., pg. 28.

[6]Neil Fabrkant and Robert Marshall Hallman, Toward a Rational Power Policy. Energy, Politics, and Pollution (George Braziller, New York, 1973).

example, central air conditioning utilizing steam would use better than 50% less fuel than an equivalent amount of electricity, and if natural gas were utilized there would be even greater fuel savings and much less thermal and air pollution. Use of an overdesigned conditioning unit should be avoided because of the surge created by off-on cycling. A well designed unit should remain running constantly.

As with the furnace a preventative maintenance schedule should be formulated and adhered to. It is reasonable to state that a general energy reduction of 10%[7] could be realized if a cooling system is kept clean and in good operating condition compared to operating the same system with dirty heat transfer surfaces, dirty filters and improper mechanical conditions.

Try to operate the cooling system at 80°F. rather than 75°F. This measure can reduce energy demand by 15%. Ventilate appliances and turn off as many lights as possible during cooling periods. Close windows and doors and (for the housewife) avoid excessive cooling during

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<u>Technical Options for Energy Conservation in Buildings</u>, Building Environment Division Center for Building Technology (Institute for Applied Technology, National Bureau of Standards, Washington, D.C., 1973), pg. 102.

the hottest weather. Encourage the use of informal light-weight clothing to accommodate the higher temperature settings. Whenever possible utilize natural ventilation rather than the air conditioning unit for comfort.

Hot water (domestic). Hot water heating has been mentioned in respect to boiler selection. More energy may be conserved if we reduce the operating hot water temperature to 120°F. This measure creates energy savings by reducing heat losses from storage tanks and piping by 20-45% and reducing energy input to hot water used for laundry and other residential uses (30% of overall daily hot water usage) where no mixing with cold water is required. A 12-15% reduction in daily energy consumption for water heating is possible. We should attempt to reduce the waste of hot water in taking showers and baths. Operate diswashers and clothes washers only at full loads to reduce the number of washings needed. Homemakers should be encouraged to use detergents designed for cold or warm water washing, thus eliminating the need for high water temperature laundry operation. The hot water tank and lines should be insulated to reduce heat loss. Leaky faucets should be repaired - one drop of hot water from a leaky faucet will amount to about 650 gallons of wasted hot water and energy over a year.[8] Recovery of heat from the hot water use, perhaps using the drain flow to pre-heat the incoming city water before it enters the heater. Combustion gases could be exhausted through a finned flue pipe which passes through the living space.

Lighting in the home is usually of a very personal nature. The greatest energy conservation may be achieved by using as much daylight and as little artificial light as possible. Be careful to turn off lights in unoccupied rooms. Fluorescent lamps are much more efficient than incandescent bulbs, so the use of the former would be advised wherever the quality of fluorescent light is feasible.

The many appliances being used in the average American homes use the following amount of kw-hr annually. The decreased use of any one of these appliances will give a reduction in energy consumption. Some suggestions for reduction of energy consumption are as follows:

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[8] Ibid., pg. 104.

Cooking Equipment[9]

1. Use cooking pots for better surface burner contact by using a pot of the same size as the burner and a flatbottom pot. Pot sides and tops may be insulated, and pots might be designed to fit snugly over burner surfaces.

2. Improved oven insulation in new appliances.

3. Reduce heat transmission and air leakage of oven doors.

4. Provide an outdoor vent for the oven for summer use.

5. Use lids for pots and pans.

6. Use thermostatically controlled stove surface units to reduce energy usage.

7. When possible, use the oven in place of surface stove units and cook several items at once.

8. On gas ranges the continuous pilot could be replaced with an electric switch operated igniter.

Refrigerator-Freezer

1. Use manual defrost units where practical.

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[9]Ibid., pg. 100.

2. Door gaskets should be checked for air leakage. If you can easily slide a dollar bill past the gasket, it leaks air.

3. Clean condenser coils to provide more efficient operation.

4. Open doors only when necessary to reduce heat and moisture gains.

Some future considerations would be:

1. Installation of a switch to shut off resistance heaters around the door opening when humidity conditions make heat unnecessary.

2. Increase thickness of box insulation.

3. Use motor compressor bearings which are more nearly friction free, and

4. Use electric motors containing more copper and steel so that interval heating losses are reduced.

Clothes Washer-Dryer

1. Use maximum size loads for washer to reduce frequency of use.

2. Use cold and warm water detergents with appropriate settings to reduce hot water demands.

3. Clean lint filters for more efficient operation.

4. Vent the dryer to outside particularly in summer.

5. Use automatic drying cycle because overdrying wastes energy.

6. Consider the use of outdoor clotheslines.

Other Appliances

1. Discourage the use of instant on television sets. Without picture tube on, these sets continuously consume energy, e.g., about 50 watts for black and white and 100 watts for color.

2. Load dishwasher completely to reduce frequency of operation.

3. Use heat producing appliances when demands on the cooling system are less - early morning, evening, and cool days.

Legislation which might be considered would include an inducement to manufacturers to increase the efficiency of their appliances, and perhaps implementation of a labeling practice whereby data on energy consumption and efficiency might be provided. Education as to proper maintenance and operation to gain maximum efficiency of the product might also be included. Manufacturers should be discouraged from developing frivolous and unnecessary appliances. They should be encouraged to spend money on research and development of more efficient appliances. Perhaps tax relief or subsidy programs might goad the manufacturers into such programs.

The All Electric House

If we are to make any progress at all in the reduction of our total consumption of energy, we must use all of our resources to their maximum efficiency. To this end, I think that the most monumental step (as well as the most responsible) the electric utilities could take would be to discourage the construction of all electric buildings. Electricity is an excellent source of power for appliances and light, but it falls far short of the mark in providing overall efficient heat or air conditioning. Electricity is the proverbial Jack of All Trades and master of none. Therefore, it would be advisable for the utilities to encourage research and development to find the most efficient uses of their product and inform the public as to what these efficient uses are. The state public utilities commission would seem like the proper forum to introduce such a proposal to the companies involved.

Insulation. Insulation is one of the easiest to install and cheapest ways in which energy consideration might be introduced into new and existing homes. For Montana's climate 6" of foil and spun glass insulation on the ceiling, 3 1/2" in the walls, a layer of foil on the floor and storm windows will reduce the energy units required to heat and cool a home by as much as 43% if gas is used and 29% if electricity is used. This represents an annual monetary savings of $45 for gas and $122 for electricity.[10] Because of these important factors, some basic information on the subject is presented here.[11]

What is Insulation?

Most materials will offer some resistance to the passage of heat. Those materials which offer high resistance to the flow of heat are called thermal insulators or simply insulation.

Which Homes Need Insulation?

Insulation is needed in all homes that use heating systems in the winter or are exposed to high temperatures in the summer. The more severe the heat or cold, the greater the need for insulation.

What Insulation Does.

It adds to your comfort because:

1. The exposed walls are warmer, and as a result less heat is radiated from your body to the cold walls.
2. There is a smaller volume of cool air moving down the wall surfaces to cause drafts near the floor.

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[10] John C. Moyers, The Value of Thermal Insulation in Residential Construction: Economics and the Conservation of Energy (Oak Ridge National Laboratory, Tennessee, 1971.

[11] Insulation in the Home (University of Illinois Small Homes Council Circular F6.0).

3. More uniform heating will be obtained throughout the home.
4. Cooler houses in summer are the result of retarded flow of heat into the house from outdoors.

Insulation saves money because:
1. Less heat loss from your home will mean less fuel required.
2. Smaller heating equipment can be used satisfactorily (This is true of new houses and replacement units).
3. In an existing house, less load on the old heating equipment makes it last longer.
4. Less cleaning of walls and ceilings is required because dust and dirt are not attracted so much to warm surfaces as to cold surfaces.

Conclusion

The basic conclusion which is drawn from this study is the fact that the major contribution residential construction operation and maintenance can make to reduce energy consumption is related to a reduction in fuel use of the heating system of the home.

The major steps which can implement this reduction in fuel consumption is the use of adequate insulation in walls and ceilings; the weatherstripping of openings and the use of double glazing in windows. New homes should be encouraged to have these features and owners of older homes should try to implement them if it is reasonably possible.

The choice of an efficient fuel for both water heating and space heating is very important to energy conservation (see Fig. II). The word efficient is an adjective which apparently has received very little attention from appliance manufacturers. This segment of our industrial society should be encouraged to use research and development to try and increase efficiency of their products.

Heating, cooling and appliances are created for human comfort more than for human necessity and it would conserve energy if we could make ourselves more tolerant to the minor inconveniences which are associated with the simple measures introduced by this paper.

We can conserve a great deal of energy by paying more attention to natural conditions of a site as evidenced by the Olgyay model. These are steps which usually require very little money to accomplish, and save both money and energy in the long run.

We should be more aware of the long range operation of the home and perhaps pay more money initially to save more money over a long period of time.

This report is written with the assumption that we will maintain our current way of life, but it is becoming evident that we cannot retain our way of life and conserve energy to a significant degree also. The man's home is his castle ethic must be reconsidered. Clustering of homes and shared facilities should be given careful consideration if the private residential sector of our society is to significantly reduce energy consumption. Shared facilities are not common to our ethic of personal ownership, so perhaps a re-education is in order along these lines.

Many areas of legislation have been mentioned; another one which might help would be the formation of an architectural review board for communities. This board would be made up chiefly of architects and engineers who would receive a nominal stipend to provide their services to all people of the community who could not or would not seek the help of these individuals. The main function of the participants would be to approve or disapprove building proposals and suggest ways the disapproved items might be made acceptable. This suggestion is meant to imply the fact we need some sort of control over chaotic, incongruous development, especially when the actions of one individual have a bad effect on the other members of the human community.

Just as society functions better in groups of people or communities, so does energy conservation work better if all aspects of the solutions mentioned are adhered to. Each part of the physical home and its operation and maintenance is knitted together into one function, to provide comfort for its inhabitants.

ENERGY CONSERVATION IN LARGE BUILDINGS

Introduction

There are many parallels between reducing energy in the home and reducing energy in large buildings, with the major difference being scale. We are trying to reduce energy consumption by reducing heat gain in summer and heat loss in winter in both types of structures. The major causes of the heat gains and losses is of a slightly different nature in the large building. Heat gains come from lights, equipment, and people, as well as the sun; losses come from infiltration.

Mechanical systems are of a much more sophisticated nature in large buildings, thus creating many more options for energy conservation. Energy may be conserved in the type of plant used as well as in the use cycling of the equipment chosen.

Most large buildings are used by many people; therefore, energy conservation in large structures becomes a means of educating large groups of people as to what good energy conserving habits are, and hopefully, these people will take this knowledge and practice the principles in their homes.

If the state of Montana would adopt the principles to their buildings, they would be educating approximately 10% of the people of the state as to how to reduce their consumption of energy.

For all practical purposes, the definition of a large building will be any structure with a floor area greater than 10,000 square feet. This is a very arbitrary figure, but it may make the size more definitive to the reader.

I. Design

Siting. The choice of a site for larger buildings is usually limited by zoning ordinances and available inexpensive land, but if the owner/developer of a building does have a choice as to where he may place the structure, then he should refer to the discussion of natural features under the topic of home siting in the previous section.

If feasible, large buildings should be located close to power generating stations. They can use the hot water for heating and electrical transmission loss will be reduced resulting in more efficient electrical power.

Of prime importance is the proximity of the building to major transportation routes of public transit systems.

The automobile is the prime source of air pollution and also a major energy consumer, so anything we can do to curtail its use will be a plus for the cause of energy conservation. Some suggestions concerning this subject as presented by the NBS/CSA Roundtable on energy conservation in public buildings on May 23, 24, 1972 were:[1]

1. To require government owned, leased and funded facilities to be located near planned or existing public transportation lines.
2. To eliminate from nonresidential design plans parking facilities in excess of those necessary to accommodate government owned vehicles; and
3. To establish a fee system for existing parking facilities which would encourage car pooling
4. To adjust the working hours of building occupants so as to avoid contributing to rush hour traffic jams.

These suggestions could also be adopted by the private sector of the nation. Management in a particular area

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[1] Technical Options for Energy Conservation in Buildings, Building Environment Division Center for Building Technology (Institute for Applied Technology National Bureau of Standards, Washington, D.C., 1973) pg. 40.

could get together to implement number four above as a group.

Combined industrial, commercial and residential communities should be encouraged whereby all daily functions could be performed within normal walking distance of a human being. In this vein, planners might be encouraged to employ spot industrial and commercial zoning near residential areas to create this convenience which reduces the use of the automobile, and makes the industrial sector more responsive to the public because of their role as neighbors.

Shape. The shape of a large building is quite often determined by what is going on inside, machinery, traffic patterns, production processes, but whenever possible, the designer should try to reduce the floor area to surface area ratio to conserve energy. In Montana's climatic conditions, closed compact buildings of a cubic shape are considered the most desirable. The environmental pressure in this region also favors higher buildings.[2]

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[2]Victor Olgyay, Design with Climate (Princeton University Press, Princeton, NJ, 1963), pg. 90.

Orientation. Proper orientation for purposes of energy conservation takes into account the factors of harsh and prevailing winds, available shade, natural elements and sun exposure, in relation to the various facades of the building. Exposure to harsh elements of the environment conserves more energy in the life of the building. This refers directly to heat radiation on sides exposed to the sun and the resultant heat gain in the building as well as accelerated heat loss due to exposure to moving air. Natural and man-made elements such as trees, hills, rock outcroppings and other buildings should be considered because of their ability to affect these natural phenomenon in both good and bad ways. An example of this would be a tree which on the one hand provides shade, but on the other hand hinders the free movement of air for natural ventilation. An environmental awareness statement might be suggested to insure that the architect and client have taken into account the physical elements to which their structure will be exposed.

Windows. Large expanses of windows have become a symbol of "modern" architecture in large buildings. Unfortunately, in many buildings the placement of windows has not taken into account orientation in relation to the sun. Therefore, there is a great deal of heat gain and an increased tonnage in air conditioning loads. Large expanses of glass also create a heat loss in winter because of the low thermal resistance characteristics of the material. Glass does have advantages in that it makes use of natural light, thus reducing lighting load. Windows provide a view to the outside which creates a psychological stimulus to man as he is able to place himself in a broader context than the room in which he finds himself.

One of the primary ways of reducing the adverse effects of large expanses of glass is by reducing the amount and size of openings in a structure.

Whenever possible, double plate glass should be used, particularly in Montana. There are also many glasses being manufactured today which reduce heat transmittance considerably, but for Montana's conditions this type of glass might have questionable merit since heat transmittance and the resulting heat gain is an advantage because of the reduction of load on the heating system during many months of the year.

Sun screens or shades, which allow the winter sun to enter the conditioned space but which repel the direct rays of the summer sun, would seem to be very appropriate in Montana.

Sun screens, if employed, should be separated from the structure as much as possible by being attached at only a few points. This is to prevent a radiator effect, whereby a fully attached screen would draw heat through the wall materials. These screens should also be detailed so they they do not get covered with ice. This may be accomplished by making the overhang of a roof extend beyond the projecting screens. Devices designed to take advantage of the sun could create a regional architectural vocabulary for large buildings, a strong psychological element which is lacking in today's architecture.

The thermal characteristics of the material chosen for window framing is important when considering energy conservation. In the Baltimore-Washington area it has been shown by testing that aluminum framing loses approximately 25% of the total window loss through the frame assembly, while wood frame assemblies lose only about 1.3% of the window loss.[3]

Movable windows as opposed to fixed panes should be employed much more in large buildings so the occupants will be encouraged to use natural ventilation in place of high energy consuming air conditioning. Many areas of Montana could get along without air conditioning quite well if a means of natural ventilation were provided in a building. The use of high quality well detailed windows will reduce the amount of air infiltration considerably, thus reducing the loads on conditioning systems.

Walls. The walls of a large building, as well as any building, should be constructed of materials which require a low energy consumption for production. The total wall system should be insulated and should be able to resist heat conductance and transmittance. Wall joints should be detailed to reduce infiltration as much as possible.

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[3] _Technical Options for Energy Conservation in Buildings_, Building Environment Division Center for Building Technology (Institute for Applied Technology National Bureau of Standards, Washington, D.C., 1973), pg. 87.

Structure. To conserve energy in the structure, it is advised that a system which uses repetitive members be employed. Simplicity of structure as well as simplicity of erection are two important factors because of the relative lack of skilled construction personnel, particularly in Montana. New construction materials and methodologies should be considered for their energy conserving attributes. We should be encouraged to take advantage of geometries and get the most work out of the least amount of material. Construction techniques should be included during the planning stages of the building. The roof and the structure should be conceived as a whole. It is better to create evolutionary designs rather than revolutionary designs.

There is a segment of energy conserving advocates who suggest that steel and concrete data and criteria for design create grossly overdesigned structures. It is the opinion of this researcher that the safety of individuals should not be compromised for the sake of energy conservation, therefore, I do not encourage that these data and criteria be reduced so that we may save on a small amount of material consumption. As a future architect, who is responsible for the creation of safe buildings, I will rely on the highly researched and developed design data presented by the various suppliers of structural design data. I reiterate, the safety of individuals should not be compromised in the name of energy conservation.

Mechanical Systems

Because of the complex nature of the interior environmental demands of large buildings, a comparison between various types of systems should be made with a computer (if possible) before a final selection is made as to what equipment will be utilized.

For data on the relative efficiencies of fuels, refer to page 28 and diagram II of this report. If there is commercial steam available for use, this should be considered for use, or if a steam electric generating plant is nearby, the possibility of using high pressure steam from the facility should be considered. The building, in effect, could be the cooling tower for the generating plant.

Making a building as self-sufficient as possible will reduce its impact on the output of local utilities and is considered an excellent energy conserving concept. In a total energy system, a fuel is consumed to fire a boiler which generates electricity and supplies the heating and cooling demands of the structure, and the domestic hot water. Use of such a system gets the maximum use out of a particular fuel.

It is advised that central heating and cooling systems be utilized, because in large buildings they have been found to use 10 to 15% less energy than small unitary package systems. It is also much easier to incorporate energy conserving devices in the larger central systems. There is the added advantage of fewer components resulting in less likelihood of equipment failure.

Oversized equipment usually operates extremely inefficiently, therefore, central systems should incorporate modular units rather than one large boiler designed for peak load efficiency. The modular system has units operating at peak efficiency, and as seasonal or daily demands dictate more heating or cooling additional units can be operating at peak capacity, or not at all, and therefore, at maximum energy efficiency. In contrast, with the single boiler the daily or seasonal fluctuations are usually below the design capacity, and therefore, there is a great deal of inefficiency in its operation. A single boiler, for example, will operate with short on-cycles of burner operation during off-peak or fluctuating demand periods resulting in reduced overall thermal efficiency. Fuel savings of around 25% are possible if the system consists of the smaller modular sized units that are independently fired to work at peak capacity and efficiency as the demand increases.

Units with multiple fuel capabilities can conserve energy. In Montana, units could be designed to adapt to burning of coal, trash or even wood by-products such as pressed logs made from timber slash. This would require study to insure that air quality would be minimally affected.

There are several heat conservation systems which save energy by utilizing waste heat. Heat recovery systems recover as much as 80% of the heat from exhausted air and put it back into the incoming outdoor air through the use of a rotary heat recovery system. A system such as this can save an estimated 30 to 35% of the energy required for heating and 15 to 20% of the energy required for electrically powered air conditioning.

Heat may be reclaimed from lighting fixtures by absorbtion in air or liquid and used for space heating or terminal reheating in an air conditioning system.

Heat storage systems to store off-peak output of heating and cooling units for later peak hour usage can reduce the peak hour cooling and heating loads as well as reduce energy consumption. A recent study on a storage type off-peak cooling system showed a 50% reduction in peak power demand and a 6% reduction in cooling consumption. Similar figures can be expected for heating operations.[4]

Waste heat can be reclaimed from incinerators, electric motors and other devices for hot water heating, space heating or absorbtion cooling; rejected heat from refrigeration units may be utilized for space heating. Hot water discharge from kitchens, laundries and lavatories may be used through heat exchangers to preheat service hot water. Exhaust air may be launched for snow melting on public sidewalks.

In selecting equipment, energy may be saved if along with initial cost an additional energy analysis were

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[4] Technical Options for Energy Conservation in Buildings, Building Environment Division Center for Building Technology (Institute for Applied Technology National Bureau of Standards, Washington, D.C., 1973), pg. 136.

required whereby the system which utilized the minimum energy for equal performance would be specified. Such a system of analysis would encourage manufacturers to develop equipment of a higher energy rating.

Low pressure HVAC systems use less energy than high pressure systems mainly because they require fewer and smaller fans. Also low resistance filter, ducts, registers, grills, and locks may add to overall energy conservation in air handling systems. Systems which simultaneously heat and cool air to control temperature and humidity multiply energy demand.

Ventilation. A reduction in ventilating air where and whenever possible will result in a reduction of energy. In some cases, reducing ventilating air by 50% can reduce power consumption of fans by 12.5% (fan horsepower can consume as much as 45% of the total building electric energy in some buildings).

This may be accomplished by reducing the ventilating air from 10-20 cubic feet per minute (cfm) per person to 4-5 cfm per person in the occupied space. Another means of reducing ventilating air is to design a system of ventilation zoning whereby ventilating air is supplied in the correct amount to areas of the building which are being used at a particular time. When these areas are not being used, the ventilating air may be reduced. An example of this would be the situation in a kitchen which might be in use for 6 to 8 hours a day. Standard practice using ASHRE Guidelines would have 12 cfm entering the space for 24 hours. With ventilation zoning, the ventilation air could be reduced 50% or more for 16 hours a day resulting in considerable energy saving. This same zoning system could also be employed to prevent overheating or overcooking of unoccupied spaces.

The possibility of natural ventilation should be considered whenever possible to reduce the burden of mechanical ventilating systems which consume large amounts of energy.

Lighting. In public buildings, lighting constitutes approximately 24% of the total electrical load, and in office buildings, lighting constitutes from 24 to 60% of the annual cooling load. These figures make it obvious that any reduction in energy used for lighting or any reduction of lighting will have a considerable effect on reduction of energy consumption in large buildings.

Reevaluation of minimum required foot candles at the working surface is in order to reduce energy consumption in lighting. There appear to be gross over design levels with no conclusive research evidence to support the necessities of such high illumination levels. These levels can be reduced without jeopardizing personal health and safety and a saving of up to 25% in energy consumption for lighting may be realized. More dramatically, by halving an illumination level, the energy requirement is cut by significantly more than 50%. For example, when artificial illumination in an area is reduced from 150 to 50 fc., the energy required drops by 90%.[5]

Uniform lighting should be re-evaluated both for its energy consuming and psychological implications. It is unnecessary to light work area to the same intensity as man work areas. Individual desk lamps might be considered to illuminate the work surface and create variety in the lighted space. Utilization of these task oriented luminaries can reduce energy consumption by 20-50% in some buildings.

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[5] Technical Options for Energy Conservation in Buildings, Building Environment Division Center for Building Technology (Institute for Applied Technology National Bureau of Standards, Washington, D.C., 1973), pg. 53.

Hallways, passageways and lobbies do not require particularly bright lighting. Reduction of maximum lighting, and omission of lighting in unoccupied spaces and where day lighting is already sufficient may reduce energy demand by as much as 50%.[6] In new buildings, interior space could be arranged so as to reduce the total amount of space to be illuminated.

Luminaries. The use of efficient equipment is of upmost importance in lighting. Fluorescent bulbs are 30% more efficient than incandescent and should be used when reasonable as a source of light. Metal halide and high pressure sodium lamps are again more efficient than fluorescent lamps, but have limited interior applications. Longer length fluorescent, higher wattage, general service incandescent bulbs, and high intensity discharge lamps are the more efficient elements of the categories mentioned.

The use of diffusing containers on light fixtures greatly reduces the overall efficiency of the unit. Since diffusers are utilized to reduce glare, it may be better to use lower illumination levels with less diffusion required.

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[6] $E = MC^2$, NBS/CSA Roundtable on Energy Conservation in Public Buildings, Report, July, 1972, pg. 53.

Surface Finishes

Lighter finishes (finishes which absorb very little light) used on floors, ceilings, walls, and furniture can increase illumination levels in a room by as much as 30 fc. Suggested surface reflectances should be in the following range (for office lighting).

ceiling finishes	80-90%
walls	40-60%
furniture	26-44%
office machinery and equipment	26-44%
floors	21-39%

Upper reflectance limits have been presented and are recommended for use to avoid overly bright surfaces which may be uncomfortable or reduce visibility through glare.

Switching. The use of switching to regulate lighting in work areas can allow for savings on the part of individuals who may be absent or who do not require maximum light levels to perform a task.

Heat transfer luminaries. Heat transfer through removing air around fixture or by passing a liquid coil through a fixture increases the efficiency of the fixture and puts the heat to use in an area where it may be required. Using this method, 30 to 80% of the total heat output of the lights can be withdrawn.

Natural illumination (daylighting). Day lighting may be used to replace artificial lighting for many tasks. The key drawback to the use of window areas to utilize daylight is the added loading created for the heating and cooling systems of the building. Shades of some form may also be required to reduce the glare of daylight. It is conceivable that through careful designing, daylighting can be employed to reduce lighting demands with a minimum impact on heating and cooling loads. Studies have shown that individuals will turn on lights whether they are needed or not, so it is advisable to utilize control systems which can turn off or reduce the amount of electric lighting when daylighting is producing adequate illumination levels.

Plumbing and water heating. Most large buildings have a circulating hot water system. Energy may be conserved by shutting off the circulating pumps during periods when the building is not occupied such as weekends and holidays. Insulation of circulating lines with 1/2" of insulation can reduce line loss of the hot water system by 50% (line loss for insulated pipe is about 30 BTU/Hr-ft and for uninsulated pipe 60 BTU/Hr-ft of pipe).[7] Installation of automatic shut-off hot water faucets are a good device for reducing WASTAGE.

Installation of solvent plumbing systems cuts down on material consumption because it negates the need for multiple soil stacks.

There has been discussion concerning the use of human wastes to produce usable gases, but at the current state of the art, the gas produced is of minimal volume and poor quality. Its use as an energy source for large buildings is not considered feasible at this point in time.

Operation and maintenance. The information included in this section is applicable to existing buildings as well as buildings in the design stages. Most of the suggestions can be easily implemented by the legislature as a step to reduce the energy of state buildings. If the

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[7] Technical Options for Energy Conservation in Buildings, Building Environment Division Center for Building Technology (Institute for Applied Technology National Bureau of Standards, Washington, D.C., 1973), pg. 104.

state will take such an initiative, and it in fact finds that energy consumption has been reduced, the public commercial and industrial sector of Montana may be compelled to follow such an example for the benefit of all involved.

Operating temperatures of heating and cooling systems. The primary consumer of energy in most large buildings are the heating and cooling systems, therefore, any reduction in their outputs will aid considerably to energy conservation. Operating these systems at 75°F should be avoided. Operating the cooling system in the summer at 78°F will result in a 16% decrease in energy consumption and operating at 70-72°F in winter will also reduce energy consumption. These operating temperatures are at the upper and lower comfort range for passive activity, so therefore, they should not create discomfort to occupants of the building. To insure comfort within the suggested ranges, employees should be encouraged to wear clothing which is approepriate to the climatic conditions of the seasons.

Automatic vs. individual control. Implications of automatic as opposed to individual temperature control of interior spaces should be evaluated in terms of human comfort and occupancy criteria. Evaluation of combinations of control systems could bring about an increase saving in energy consumption.

Lowering temperature. Operating temperatures could be reduced during times of minimum occupancy of a building, such as weekends, holidays and evenings, resulting in a reduction in energy consumption. Likewise meetings or activities beyond normal occupancy hours could be scheduled in rooms which have an individual temperature control. Temperature in hallways and lobbies may be reduced a few degrees with little effect on human comfort. Personnel who work in these areas could have a localized unit heater for their work space.

System shut off. Employees should be encouraged to shut off cooling systems before the end of the working day. This practice uses the latent cooled air of the room for the remainder of the occupied time, and reduces the peak demand load on electrical utilities.

Doors. For Montana's cold climate, a double set of doors, or revolving door, or an air door is recommended to reduce the amount of cold air which may directly enter the conditioned space. Automatic door closures are recommended because of people's habits of leaving doors open, even in winter months.

Natural heating and cooling. During winter months sun which enters the space during the day can reduce the heating load. At night, drapes should be pulled to help reduce heat loss. In the summer, open windows will permit cool air to enter the enclosed space. If these windows are shut during the day, the need for cooling will be minimized.

Equipment maintenance. A preventive maintenance program should be implemented for heating and cooling systems of a building. Included in this maintenance should be:

1. Cleaning of heat transfer surfaces.
2. Adjustment of burner and combustion air.
3. Cleaning or changing of air filters.
4. Motors should be oiled and bearings lubricated.
5. Keep condensers free of foreign materials.

Implementation of these measures could result in a 10% saving in fuel consumption.

Pipes and ducts. All pipes and hot water and steam hot air ducts passing through cooled space should be insulated to increase the efficiency of the system of which they are a part. Hot water circulating pumps should be turned off when the building is not occupied. Leaky faucets should be repaired to reduce the waste of hot water (self shut-off faucet may be used to reduce waste also).

Lighting. Lighting accounts for 24% of all the electricity sold in the U.S., and most of this is for larger structures. Lights also add considerably to the total heat gain of a structure in summer. Therefore, any reduction in lighting will add measurably to reduction of energy consumption. Employees should be encouraged to shut off lights when an office is not in use. Lights should be turned off in frequently unoccupied spaces such as storerooms and bathrooms. Light sensitive switches might be employed to activate lights only when daylight is not adequate to supply the necessary lighting level. Lights should be regularly cleaned to increase output efficiency of the lighting units. Some janitorial activities could be performed during working hours. This can reduce the necessity of night lighting of large areas for a few individuals.

<u>General</u>. Operating personnel should be reminded that in order to conserve energy heating and cooling equipment should be used sparingly. During approximately 500 of the 3,100 hours per year that a typical office building is occupied, outside air can be introduced into the ventilating system with neither preheating or precooling. This factor alone can result in a 20% reduction in energy required for air handling.

Smoking should be limited to a few specified zones because of the increased neutilation load required on these areas. The energy conserving implications of a four day week should be studied by qualified groups. It is possible that more energy may be consumed by employees recreating through working (snowmobiles, power boats, autos, etc.).

Individual employees should be encouraged to:[8]

1. Turn off window air-conditioning units shortly <u>before</u> the end of the business day.
2. When individual window air-conditioning units are provided, close the damper which admits outside air while the equipment is used for cooling.

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[8] <u>$E = MC^2$</u>, NBS/CSA Roundtable on Energy Conservation in Public Buildings, Report, July, 1972, pg. 58.

3. Report leaky water faucets and radiators immediately.
4. Draw or partially close blinds, shades and draperies on the sunny side of a building in summer.
5. Do not keep windows or outside doors open unless authorized to do so during heating and cooling seasons.
6. Utilize the minimum artificial lighting during daylight hours in rooms provided with adequate windows or skylight illumination.
7. Keep unnecessary lights turned off such as those in storerooms, closet or other spaces not being occupied.
8. Shut off lights when leaving the office or other work area.
9. Turn off electric fans, coffee makers and other appliances when not required, particularly during peak load periods.
10. Use stairs when possible, instead of elevators, particularly at quitting time.
11. Practice energy conservation at home.

Design Analysis Systems

Life cycle costing analysis considers operating costs along with first costs in making design decisions. This type of analysis has the benefit of being biased towards equipment and designs which show greater energy efficiency.

Through this sytem the additional cost of such items as sun screens and greater insulation can be justified by savings in heating and cooling. More expensive heating and cooling equipment may be purchased if it uses less energy over its operational life to perform the same job. Energy conservation becomes more appealing in business terms when we see accelerating energy costs projected over a 40 or 50 year period.

Life cycle costing can be expected to foster energy conservation by 1) bringing about a reduction in energy demand by cutting energy losses, 2) selecting more efficient energy conversion systems, and 3) moving toward greater utilization of freely available energy to supplement present sources.[9]

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[9] Technical Options for Energy Conservation in Buildings, Building Environment Division Center for Building Technology (Institute for Applied Technology National Bureau of Standards, Washington, D.C., 1973), pg. 29.

A second analysis technique is cost benefit analysis. This system compares the quantity and quality of alternate means for satisfying an objective. The analysis ranks the alternatives according to the degree of economic efficiency with which they achieve a specific goal and rates qualitative consideration within the rankings. This form of analysis is also geared to consider long range operating costs and because of this, it is more favorable to energy conservation goals than existing procedures that include only the initial cost of construction.

The state of Montana could adopt one of these forms of cost analysis and actually save money during the life of a building as well as save energy. Both should be employed at the design and early decision making stages of the structure.

Conclusion

The facts presented here are of an advisory nature, and as such they will do nothing toward reducing energy consumption until they are implemented by persons owning, operating or designing a large building.

If a new building is designed following the guidelines presented in this report, there can be expected at least a 20% reduction in energy consumption.

Secretary of the Interior Morton has suggested that the type of information contained this report falls under the category of jawboning. Energy conservation must evolve from our current technology, skill and knowledge of fundamentals. This report reviews many of these common sense fundamentals so that they may become common knowledge and useful to all. Revolutionary ideas and their resultant short term advantages have very little place in the long term problem of energy conservation. It is emphasized that the information mentioned herein is meant to be a foundation for energy conserving principals in our public buildings and private homes.

NEWER FORMS OF ENERGY

NEWER FORMS OF ENERGY

It appears obvious that the fundamentals described in the preceding chapters will only buy us time, and will not truly alleviate the consumption of our nonreplenishable (except hydro) conventional forms of energy.

As the cost of these forms of energy increase under the principle of supply and demand, other "experimental" forms will come into common use through economically competitive channels. These experimental technologies which come under the disguise of "new" forms of energy include such "new" phenomena as the wind, the sun, the tides, and geothermal activity. Some truly new technologies have been developed in the area of atomic breeder reactors, fuel cells and magneto-hydrodynamics. A fundamental familiarity of these types of energy will be helpful for understanding the future developments which seem imminent in our national energy picture.

Wind Energy

Wind has been utilized throughout history to pump water, grind grain and propel vehicles and ships. It has been used to generate electricity in rural areas for the last 50 years. The technology for its use is well developed, but it is not economically competitive with conventional forms of energy.

The application of wind energy for buildings would come at a residential scale and would be most feasible for rural areas. These two factors make it a particularly attractive form of energy for Montana.

Solar Energy

Indirectly, solar energy has been utilized by man for millions of years. Firewood, coal, foodstuffs, and, more recently, oil and gas have all been created by solar energy. Direct use of solar energy is a relatively new technology and has been applied mainly in Arizona and Nevada where there is a great deal of uninterrupted sunshine. Solar energy may be used for heating or, in many cases, to generate electricity. It is being developed mainly at a residential scale and could be considered for use in Montana. Solar heat could be utilized to heat domestic hot water on larger structures. There is a need to refine technology in this very promising, non-polluting energy source.

Geothermal Energy

Heat from hot rocks or aquifers in the earth may be used directly to heat structures or to run turbines to produce electricity. Water used in such a system could be returned to the earth to be reheated. The occurrence of hot springs and other geological phenomena place Montana in an excellent position to develope this form of energy. Geothermal heating systems are in use in Iceland, New Zealand and California and have had very favorable performance.

Tidal Energy

Electricity is produced in generators exposed to the rising and falling of a head created between tidal cycles. This is a reusable and dependable form of energy, but it does not apply to Montana's inland situation.

Nuclear Breeder Reactor

"Liquid-metal fast breeder reactors" are considered to be our best hope for power production in the future. Basically, this type of reactor produces more fuel than it burns by its chemical process of converting uranium to platinum. This type of reactor can increase our uranium supplies a hundred fold. Breeder reactors produce less heat loss and less radioactive waste than conventional nuclear reactors, and since they operate at a much lower pressure, the chances of leakage of radioactive gas is less.

Fuel Cells

Fuel cells have been developed by our space programs. This is a non-polluting energy producer that takes kerosene or No. 2 fuel oil and converts it chemically into electricity. By-products of this process are water vapor and CO_2. Technology is being developed by some major companies to create a ten to fifteen megawatt fuel cell which may be placed on top of large buildings. This is expected to be ready for use in the early 1980's.

Magneto Hydrodynamics

This source of energy uses the principle of ionization of superheated (5500°) gases. It is claimed that the efficiency of MHD is 1 1/2 times that of a conventional fossil-fuel power plant.

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